Southwest Fisheries Center Administrative Report No. 19H, 1978

ASSESSMENT OF THE ARMORHEAD STOCK ON THE MID-PACIFIC SEAMOUNTS

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August 1978

This is a background document prepared for the Western Pacific Regional Fishery Management Council Seamount Resources Planning Team. It will not be published in the present form and should not be cited in the literature.

Stock Identity

The first task in assessing the armorhead resource is to come to some judgment on stock structure and identity. If the stock and fishery dynamics on the Hancock Seamounts are independent of events occurring elsewhere, then the Hancock armorheads can be treated as a unit stock. Stock assessment can then be attempted using data on the catch and effort history of just the Hancock Seamounts fishery, and a rational management policy can be developed without necessarily considering activities on other seamounts in the region. On the other hand, if the armorheads on Hancock are from the same stock as those exploited further out on the seamount chain, the stock assessment must be based on catch statistics representing the entire range of the fishery, and the policy analysis will have to consider the implications of fishing outside the Fishery Conservation Zone (FCZ).

At this juncture it must be pointed out that two "types" of armorhead are recognized, a "fat type" with a relatively deep body and the blue-over-white coloration typical of many surface swimming fishes, and a "lean type" with a much shallower body and uniformly gray coloration. The two types tend to occupy different habitats--the fat form inhabiting the surface waters of the northeastern Pacific and the lean type being associated with the seamounts of the central North Pacific. Some of the fat type armorheads also occur on the seamounts, but lean fish usually predominate there. Armorhead catches by the _Ryoyo Maru No. 2_ in April-June 1978, were essentially 100% lean type on Hancock and Kinmei Seamounts, although 37% of the armorheads sampled from catches on the Colahan Seamounts were of the fat type (Kazama 1978). Even among lean fish there are a variety of forms; the Hancock Seamounts are noted for a relatively high proportion of "very lean" armorheads, brownish in color, elongate and with a very thin and delicate skin.

Whether this wide range in form represents genetic polymorphism in the species or is a result of differences in habitat and environmental factors alone remains to be determined. If there is just one integral stock of armorheads in the entire North Pacific, then we have no basis for assessing it, since the seamount fishery covers only a tiny part of the whole range. We assume hereafter that the "fat type" and "lean type" fish are from different stocks, and that the armorheads on the Hancock Seamounts inside the FCZ are members of a single stock of lean armorheads occupying the entire seamount chain (the presence of fat type armorheads on some of the seamounts is assumed of negligible consequence).

There is a considerable body of evidence sustaining the idea of a single, homogeneous stock on the seamounts. Specifically,

(1) The species has pelagic, free-floating eggs and larvae, so that a considerable degree of intermingling of offspring from adults inhabiting closely adjacent seamounts is likely;

(2) Catch rates of Japanese trawlers operating on the Hancock Seamounts during the period 1969-76 are virtually identical to the aggregate catch rates experienced by the same fleet over the entire range of seamounts. Density of armorheads in any given year appears to be

similar on the different seamounts, and annual variations in density tend to follow the same pattern;

(3) The size composition of armorhead catches in the Japanese trawl fishery is the same on all seamounts in the range.

Although these observations certainly support a common-stock hypothesis, it is not clear what factors govern recruitment or occupation of the seamount habitats by armorheads. Nor is it understood why the stock density would be so nearly the same on Hancock as on the other seamounts.

Index of Abundance

Assuming a single stock of armorheads on the seamount chain, we can construct an index of stock abundance using the aggregate catch

Table 1

per unit effort statistics of the Japanese trawling fleet. Table 1 shows the annual sequence of catch rates from 1969, when the Japanese fishery began, through 1976. According to Takahashi and Sasaki (1977), the first 3 years were developmental in nature, and it was not until 1972 that the fleet's operations stabilized. From 1972 through 1976 the total Japanese armorhead catch has ranged between 18,950 metric tons (MT) and 34,450 MT, while effort has increased from 550 h of trawling to 2,670 h. The average catch rate over the 5-yr period has dropped steadily from 60.2 MT/h to only 9.7 MT/h.

The steady decline in the index of abundance over 1972-76 may be due to a number of plausible factors, including (1) declining trend in recruitment, (2) increasing fishing mortality rate, or (3) declining trend in availability of armorheads on the seamounts. The first factor would involve an actual decrease in the number of armorheads reaching the minimum harvestable age (about 3-4 yr), whether due to decreased egg production in the preceding years or increased natural mortality of pre-recruits. [The reduction in egg production might in turn be caused by high fishing mortality on mature armorheads.] The second factor, given constant recruitment, involves progressively fewer armorheads being caught in the older age groups relative to the harvest of younger recruited fish, and a general reduction in the average abundance of exploitable armorheads. The third factor implies some process whereby seamounts, as only one of several possible habitats, are occupied by armorheads of harvestable size periodically, and the fraction of the stock actually occurring there, available to the trawlers, varies from year to year.

To determine which one of these factors (or which combination) might underlie the declining index of abundance, one must examine other data. Some insight is provided by the information on fishing effort and size composition of the catch. The increasing effort trend (Table 1) suggests a corresponding increase in fishing mortality rate, providing availability did not decrease substantially during the period. On the other hand, an increase in fishing mortality rate is inconsistent with the observed shift in the length composition
Fig. 1 of armorheads (Figure 1) between 1972 and 1976. Rather than a shift toward small fish, there was apparently a trend toward larger armorheads in the trawl catches. This would suggest perhaps a decrease in fishing mortality rate (assuming constant recruitment), which might result from a sharp decline in availability. Such a fall-off

in availability would also explain the reduction in the abundance index. Another possibility is that the increase in fishing effort did indeed produce a corresponding rise in the fishing mortality rate, and that the changes in length composition of armorhead catches were a result of a pulse increase in recruitment in 1972. Still another possible explanation of shifts in the size distribution would be variable influxes of "fat type" armorheads into the population of predominantly "lean type" fish. An increase in the relative abundance of fat fish would tend to shift the distribution downward, and vice versa. Clearly there are many permutations of assumptions which would be compatible with the meager observations at hand.

Total Catch and Total Effort

Two nations have participated in the seamount trawl fishery on mid-Pacific seamounts--Japan and the U.S.S.R. Japanese catches of armorhead and alfonsin are given in Table 2 after Takahashi and Sasaki (1977). They are not reported in the 1976 Yearbook of Fishery Statistics published by FAO. On the other hand, the Soviet catches of alfonsin are reported in the FAO Yearbook, but armorhead catches are not given and no other source of U.S.S.R. catch data is available.

Table 2

To estimate the total armorhead catch, we could compute the ratio of Soviet alfonsin catch to Japanese alfonsin catch on the seamounts and then simply expand the Japanese armorhead catch statistics, assuming the same species composition in the catches. But the resulting ratio is about 16:1, and the projected Soviet armorhead catch is unreasonably large. Thus there is no available estimate of the total catch of armorheads, and no available estimate of total effective effort on the armorhead stock that can be supported statistically.

In the production model analyses described below, it was assumed that the Soviet armorhead catch each year, 1972-76, was equal to the Japanese catch. Total effective fishing effort was then computed be dividing the estimated total catch in a given year by the corresponding index of abundance. The assumption on the Soviet catch probably puts the total catch at the correct order of magnitude, at least. In the analysis, whether the Soviet and Japanese catches are equal is not important so long as the ratio between them is the same each year.

Production Model Analysis and Estimates of Maximum Sustainable Yield

A surplus production model (Schaefer model) was used to estimate maximum sustainable yield (MSY) and the associated optimum fishing effort (EOPT) for the seamount armorhead stock. The model assumes that the reduction in the index of stock abundance was a linear function of increased fishing effort, and that recruitment and availability were constant over 1972-76. It ignores information on length composition.

The model is an equilibrium yield model, whereas the raw data represent transitional states in stock size and effort. The Gulland method of effort-averaging was used to approximate equilibrium conditions. The average effort in a given year was computed as the mean of the actual effort in that year and the actual effort of the preceding year. As a result of the effort averaging, only four data points remained for the analysis, 1973-76. For purposes of comparison, the production model was also fit to the full data set, i.e., the five pairs of catch rate and actual effort.

Figs. 2, 3

Results of the production model analysis are given in Figures 2 and 3. Figure 2 presents the relationship between the index of abundance and the averaged and unaveraged measures of effective effort, and the fitted regression lines. Figure 3 shows the resulting yield-effort curves. The estimated MSY is 76,500 MT of armorheads in the case of unaveraged effort, and 52,600 MT when the smoothed effort statistics are used. Corresponding optimum fishing effort estimates are 2,800 and 2,400 trawling hours. Because the effort averaging presumably corrects for nonequilibrium biases which result when the actual annual catch and effort statistics are used, the best estimates for MSY and EOPT are here assumed to be 52,600 MT and 2,400 trawling hours. This effort figure was exceeded in 1975 and 1976 (Table 1).

These estimates of armorhead MSY and optimum effort refer to the hypothesized single stock occupying the entire mid-Pacific seamount range. Further, the analysis assumed the Soviet catches were equal to the Japanese harvests each year. If the latter assumption is incorrect, the production model analysis is still useful so long as there is no change in the ratio of Soviet to Japanese catch over the years. Suppose this ratio is θ. Then the standard estimates of MSY and optimum effort (given above) can easily be adjusted according to the formulas:

$$\text{Adjusted MSY} = \left(\text{Standard MSY}\right)\left(\frac{1 + \theta}{2}\right)$$

and

$$\text{Adjusted EOPT} = \left(\text{Standard EOPT}\right)\left(\frac{1 + \theta}{2}\right) \quad .$$

If θ is not constant from year to year, the production model analysis given here is invalid. It would have to be repeated using the complete records of Japanese and Soviet catch.

How about the effects of other assumptions? Not much can be said about availability without independent information on stock size and distribution. But concerning recruitment, if we assume there was a pulse increase in recruitment in 1972 (consistent with observed shifts in length composition), then the production model analysis is probably conservative. That is, the impact of fishing effort on the abundance index is not as great as the model suggests and recent effort levels may actually be less than EOPT.

Optimum Yield, Domestic Capacity and Total Allowable Level of Foreign Fishing

The Fishery Conservation and Management Act (FCMA) requires that a Fishery Management Plan (FMP) specify the optimum yield (OY) for each species under consideration, compute the expected domestic catch capacity, and determine the surplus (if any) available for harvest by foreign fleets. There are serious conceptual difficulties in the case of armorheads, akin to the problems faced in the Pacific billfish FMP. Our basic assumption is that armorheads are essentially "highly migratory," or at least that only a small part of the stock occupies habitat within our FCZ and is subject to our direct control. This severely conditions the "optimality" of our yield policy, and alters the usual list of management policy considerations.

Putting this problem aside, a variety of criteria may be applied to evaluate alternative policies and to help define an optimal one. These might include:

(1) Maximize armorhead harvest subject to biological productivity constraints. For example, encourage more fishing, but make sure the total fishing effort does not exceed the level, EOPT, producing the MSY.

(2) Ensure continued collection of data for stock assessment. Since the catch rates on the Hancock Seamounts provide an index of the entire stock's abundance, a reasonable amount of foreign fishing on Hancock would be valuable.

(3) Maximize profit potentials for U.S. vessels wishing to exploit the armorhead stock. Maintain stock size at high levels, allowing prospective domestic fishermen to enter the fishery with relatively high catch rates.

(4) Protect other seamount resources of value to the U.S., such as precious coral, which may be taken inadvertently in the course of trawling.

This list could easily be extended, but it states most of the key management objectives. How are the criteria affected by the peculiarities of the armorhead resource? Certainly objective (1) will be impossible to achieve solely by U.S. action; only a small fraction of the stock is inside the FCZ and only part of the catch is taken there. Virtually nothing can be done unilaterally by the U.S. to ensure that EOPT is not exceeded. The same goes for the third objective. Because the stock is exposed to fishing outside the FCZ, the stock size and hence catch rates are determined by factors outside U.S. control. In terms of our ability to establish effective management policy, only criteria (2) and (4) seem to be meaningful. A reasonable policy with respect to foreign fishing would therefore be to:

(1) Encourage foreign armorhead trawling at levels established in recent years (i.e., about 2,000 MT/yr), and collect detailed data on the catch, effort, and other aspects of the fishing activity,

(2) Establish guidelines for the incidental take of coral and other species of value to the U.S.

(3) Promote the careful assessment of the armorhead stock over its entire range and draw attention to the need for international management action if the health of the stock is threatened.

Assuming this would be the "optimum policy," then the associated optimum yield is

$$OY = 2{,}000 \text{ MT/yr}$$

Apparently there is no immediate U.S. interest in harvesting armorhead, so we can assume the domestic annual harvest will be zero. This leaves us with a Total Allowable Level of Foreign Fishing (TALFF) equal to the OY, or

$$TALFF = 2{,}000 \text{ MT/yr}$$

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Table 1.--Catch and effort statistics used in assessing the armorhead stock. Total effort and catch assumes Soviet catch equal to Japanese catch.

Year	Observed			Assumed total effort		Assumed total catch	
	Japan catch (10^3 MT)	Japan effort (10^3 h)	Japan C/E (MT/h)	1-yr (10^3 h)	2-yr (10^3 h)	1-yr (10^3 MT)	2-yr (10^3 MT)
1969	8.28	0.16	20.9	--	--	--	--
1970	30.05	2.81	10.7	--	--	--	--
1971	5.89	1.30	4.5	--	--	--	--
1972	29.88	0.50	60.2	1.00	--	59.76	--
1973	25.05	0.74	33.8	1.48	1.24	50.10	41.78
1974	34.54	1.59	21.8	3.18	2.33	69.08	50.75
1975	18.95	1.38	13.8	2.76	2.96	37.90	40.92
1976	25.80	2.67	9.7	5.34	4.04	51.60	39.23

Table 2.--Japanese trawling effort and associated catches of armorhead over the central North Pacific seamounts and over the Hancock Seamounts, and the percentage of catch and effort expended on Hancock in relation to the total seamount area.

Year	All central North Pacific seamounts (including Hancock)			Hancock Seamounts			Percentage of catch and effort on Hancock Seamounts	
	Catch (MT)	Effort (h)	C/E (MT/h)	Catch (MT)	Effort (h)	C/E (MT/h)	Catch (%)	Effort (%)
1969	8,280	157	20.892	--	--	--	--	--
1970	30,047	2,807	10.704	180	17	10.588	0.6	0.6
1971	5,891	1,304	4.525	221	51	4.333	3.8	3.9
1972	29,880	496	60.242	1,994	24	83.083	6.7	4.8
1973	25,047	740	33.847	8,518	212	40.179	34.0	28.6
1974	34,538	1,588	21.818	1,744	75	23.253	5.0	4.7
1975	18,952	1,377	13.763	653	42	15.548	3.4	3.0
1976	25,795	2,667	9.672	1,112	101	11.010	4.3	3.8

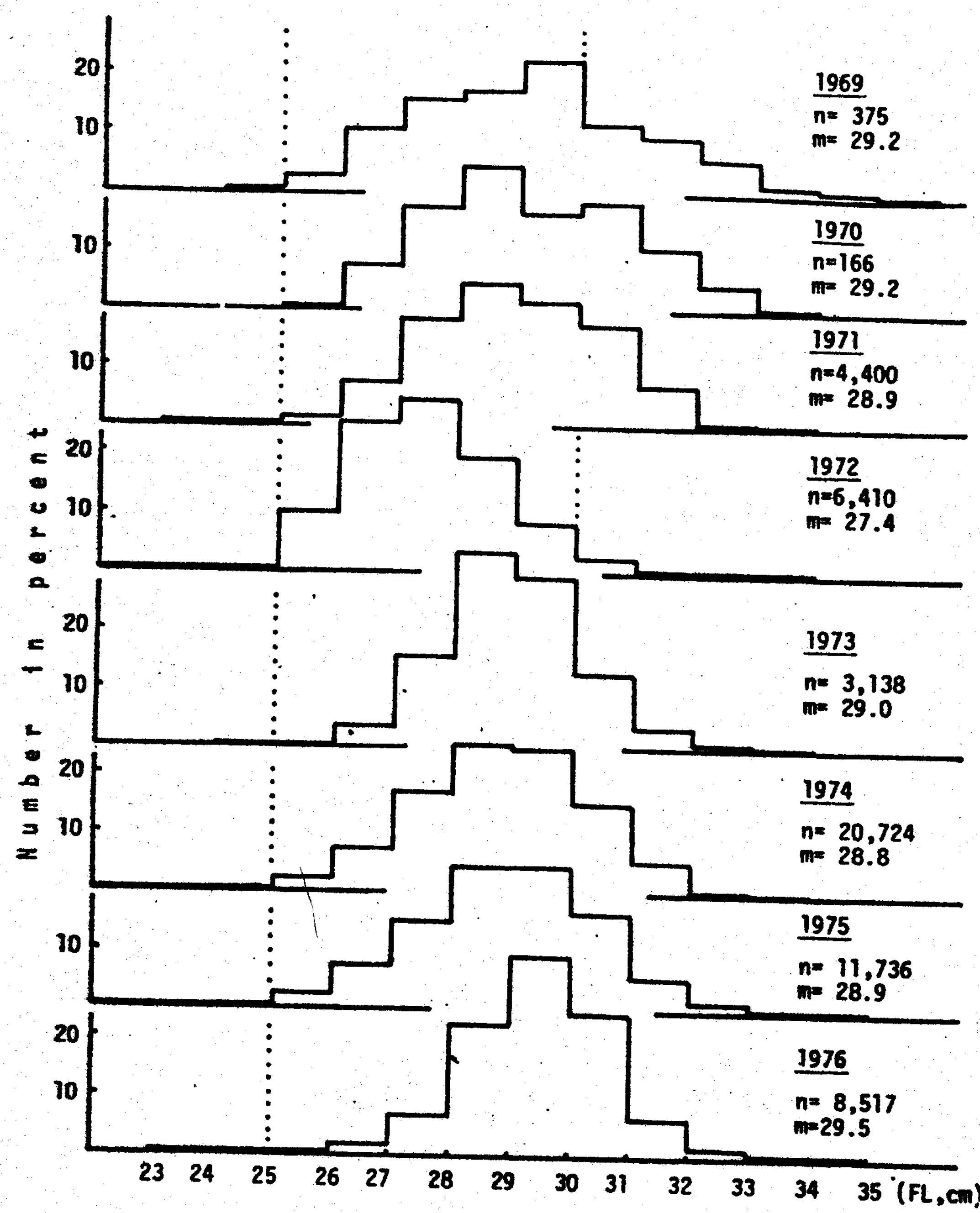

Fig. 4 – The fork – length composition of armorhead in th trawl fishery on the central North Pacific Seamounts, 1969 – 76.
n : number of individuals sampled. m : average fork – length (cm)

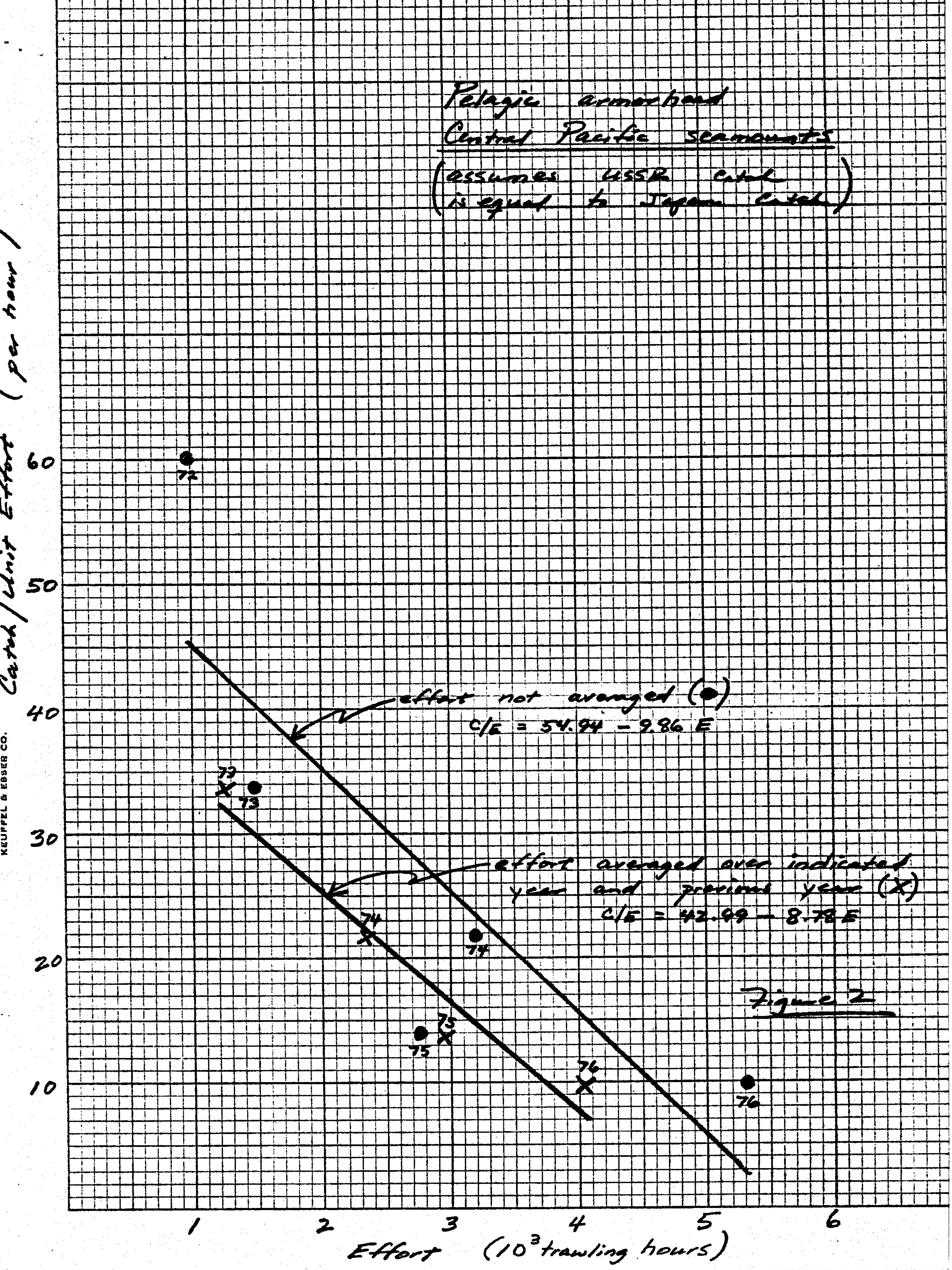
Pelagic armorhead
Central Pacific seamounts
(assumes USSR catch is equal to Japan catch)
effort not averaged (●)
C/E = 54.94 − 9.86 E
effort averaged over indicated year and previous year (X)
C/E = 42.99 − 8.78 E
Catch/Unit Effort (metric tons per hour)
60
50
40
30
20
10
72
73
74
75
76
1
2
3
4
5
6
Effort (10³ trawling hours)

Figure 2

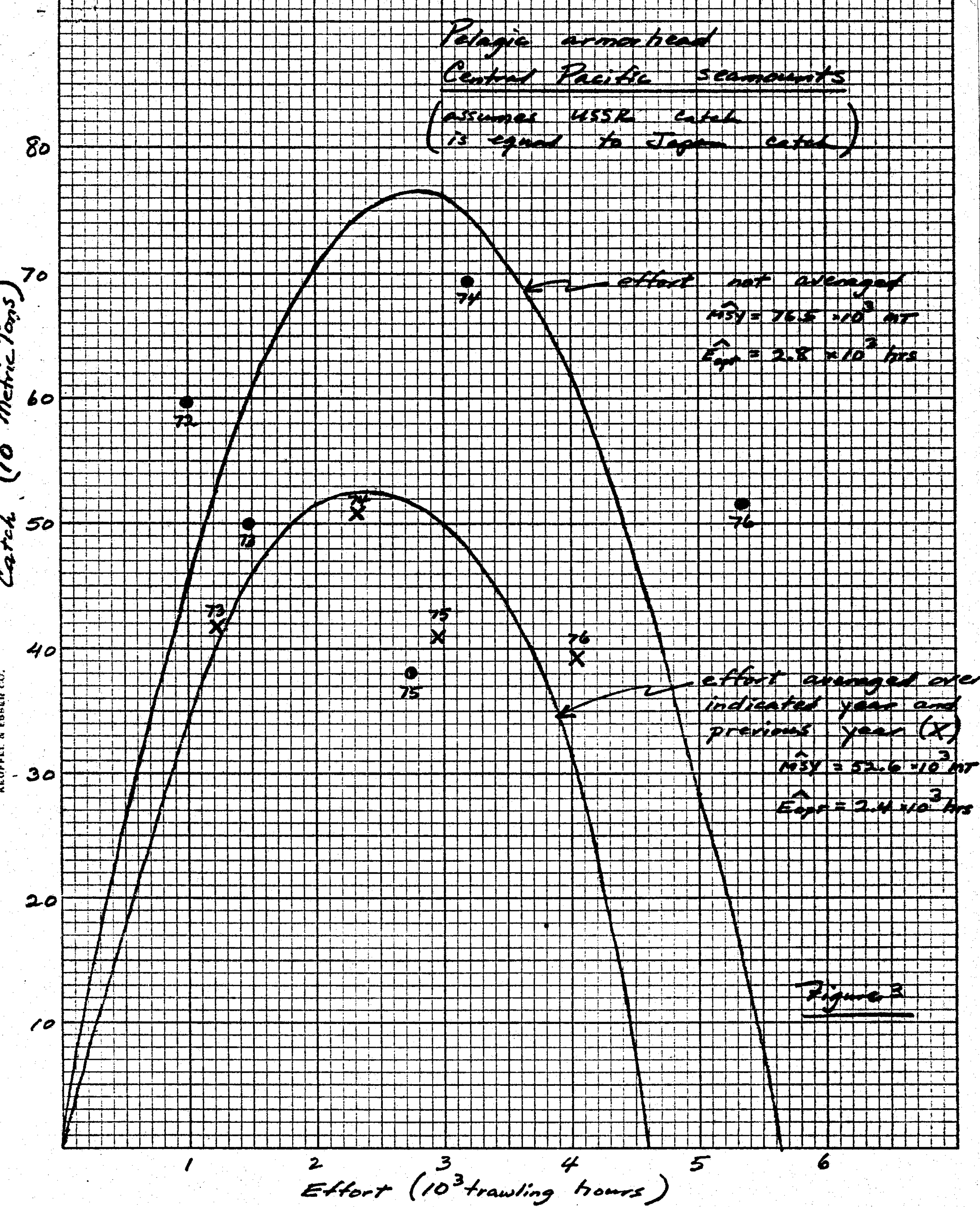
Pelagic armorhead
Central Pacific seamounts
(assumes USSR catch is equal to Japan catch)
effort not averaged
$\widehat{MSY}$ = 76.5 × 10^3 MT
$\hat{E}_{opt}$ = 2.8 × 10^3 hrs
effort averaged over indicated year and previous year (X)
$\widehat{MSY}$ = 52.6 × 10^3 MT
$\hat{E}_{opt}$ = 2.4 × 10^3 hrs
Catch (10^3 Metric Tons)
Effort (10^3 trawling hours)
72
73
74
75
76
10
20
30
40
50
60
70
80
1
2
3
4
5
6

Figure 3